



WBS 6.4

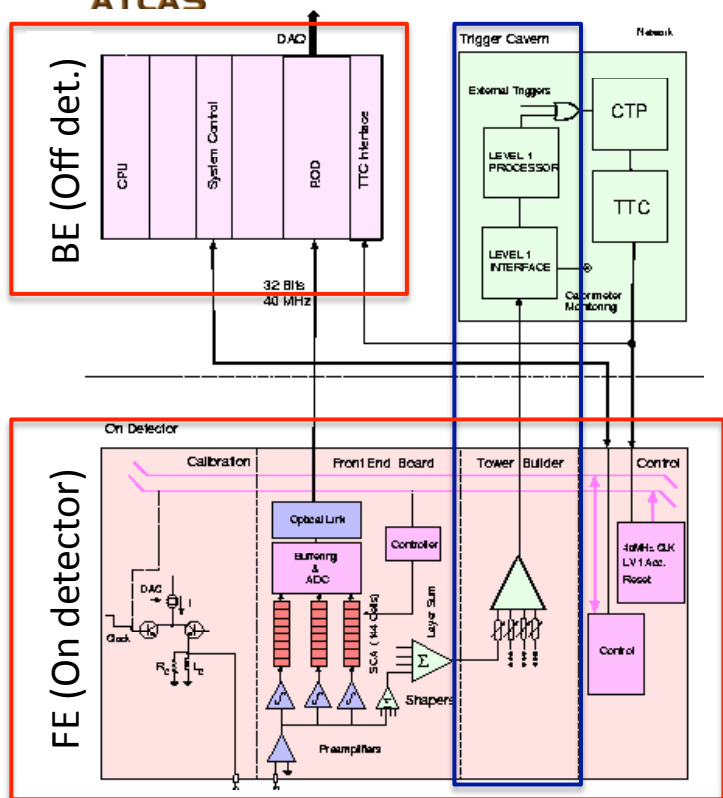
Liquid Argon Calorimeter System Management Overview

John Parsons
US ATLAS HL-LHC Level-2 Manager for the LAr Calorimeter System
Columbia University

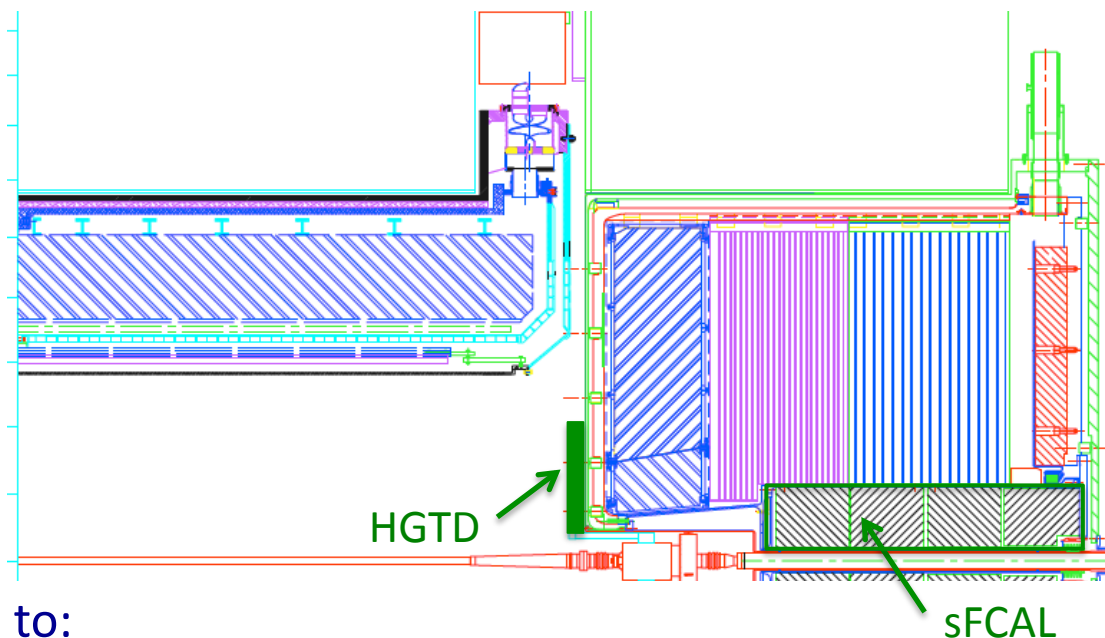
First HL-LHC LAr Weekly Meeting
May 9, 2016



LAr Calorimeter System



- In Phase I, upgrading L1 trigger electronics to be able to cope with lumi of 2E34



- LAr HL-LHC upgrade plans are to:
 - Replace LAr readout electronics, both front-end (FE) and back-end (BE)
 - Possibly modify the forward region, with options including
 - Possible new sFCAL to replace FCAL (or possible MiniFCAL in front of FCAL)
 - Possible high-granularity timing detector (HGTD) in front of endcap cryostat

Scope
Opportunity



LAr WBS Structure and Institutions

From CDR

6.4 Liquid Argon WBS (NSF)	
Deliverable/Item	Institution
FE Electronics	
6.4.1.1 FE Electronics	Columbia
6.4.2.1 FE Electronics	UT Austin
Optics	
6.4.3.2 Optics	SMU
BE Electronics	
6.4.4.3 BE Electronics	Stony Brook
6.4.5.3 BE Electronics	U Arizona

6.4 Liquid Argon WBS (DOE)	
Deliverable/Item	Institution
System Integration	
6.4.6.4 System Integration	BNL
PA/Shaper	
6.4.6.5 PA/Shaper	BNL
6.4.7.5 PA/Shaper	U Penn
sFCAL	
6.4.5.6 sFCAL	U Arizona
HGTD	
6.4.7.7 HGTD	U Penn
6.4.8.7 HGTD	UCSC
6.4.9.7 HGTD	SLAC
6.4.10.7 HGTD	U Iowa

Scope Opportunity

- 8 university groups and 2 labs
- US deliverables organized into 7 BOEs
 - 5 in baseline (3 NSF, 2 DOE)
 - 2 in “Scope Opportunity”



Mgmt Updates Since CDR

- “Deliverables Managers” and Institutional PIs have all been appointed
 - In this process, reorganized WBS a bit, splitting off ADC development from FEB2, and combining with optics into “FE Components” item
- US ATLAS HL-LHC LAr management team and tasks are:
 - **WBS 6.4.x.1 FE Components** (Tim Andeen)
 - Columbia (J. Parsons), SMU (J. Ye), UT Austin (T. Andeen)
 - **WBS 6.4.x.2 FEB2 Board** (John Parsons)
 - Columbia (J. Parsons)
 - **WBS 6.4.x.3 BE Electronics** (Andy Haas)
 - Stony Brook (J. Hobbs), U Arizona (K. Johns)
 - **WBS 6.4.x.4 Syst. Integration** (Marc-Andre Pleier)
 - BNL (H. Ma)
 - **WBS 6.4.x.5 PA/Shaper** (Hong Ma)
 - BNL (H. Ma), U Penn (M. Newcomer)
 - **System engineer** (Hucheng Chen)
- Other documents (BOEs, budgets, etc.) not yet modified to reflect WBS reorganization

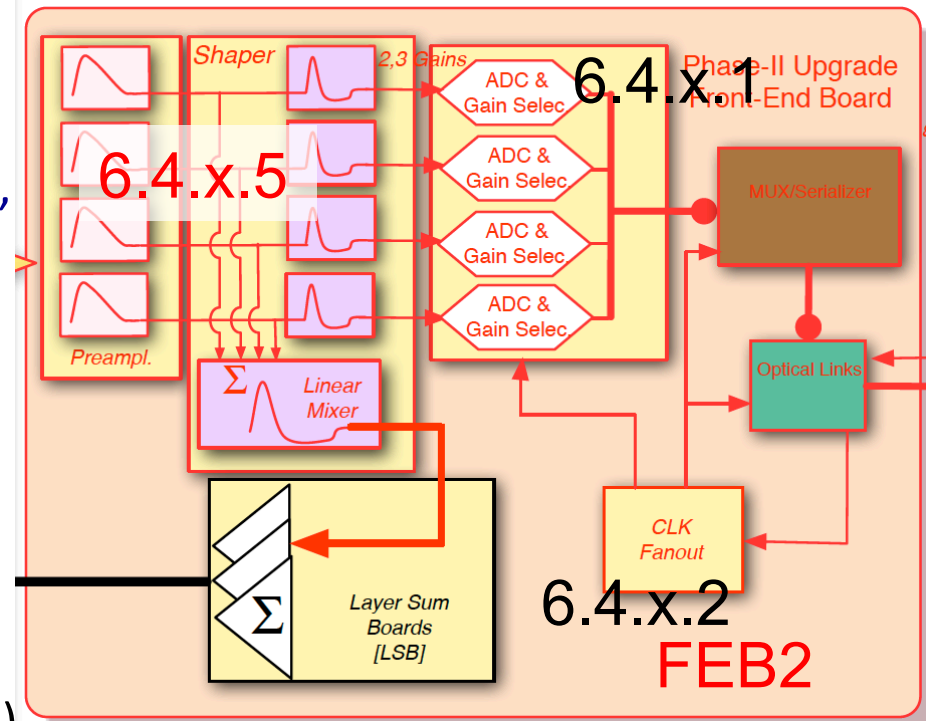
NSF

DOE



HL-LHC LAr FE Electronics

- As in original construction, US groups proposing to take lead responsibility for electronics in LAr FE readout path, with deliverables including:
 - Radiation-tolerant (65 nm) ASICs
 - Preamp/shaper (BNL, U Penn)
 - 40 MHz ADC (Columbia)
 - 10 Gbps Serializer (SMU)
 - VCSEL array driver (SMU)
 - Optical transmitter (OTx) (SMU)
 - Frontend Board (FEB2) (Columbia)
- WBS items: **6.4.x.1 (FE Components)**, **6.4.x.2 (FEB2)**, **6.4.x.5 (PA/shaper - DOE)**
- Apart from complementary French effort on Preamp/shaper, no non-US groups are currently working on these tasks
- Full system of ~170k channels requires 1524 FEB2 boards (128 channels each)
 - As in original construction, planning to produce total of 1627

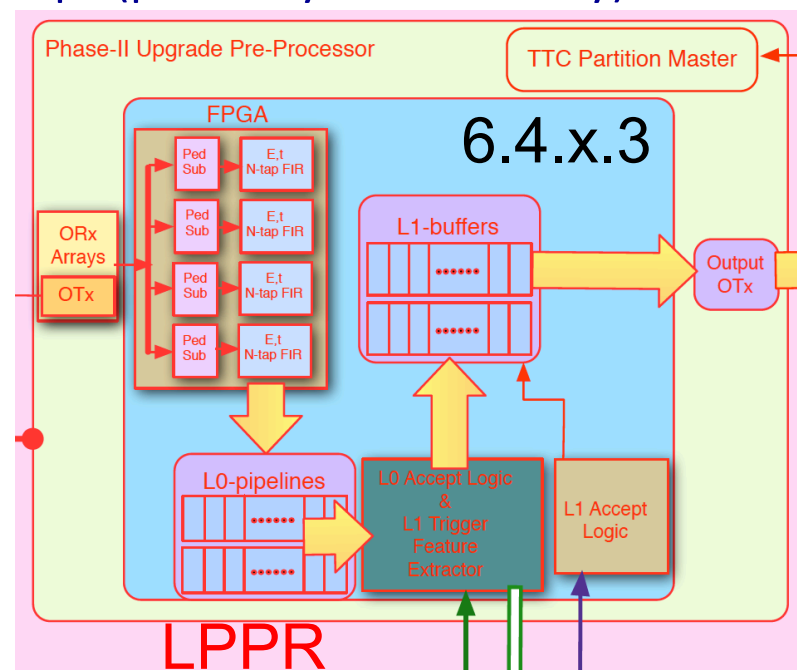
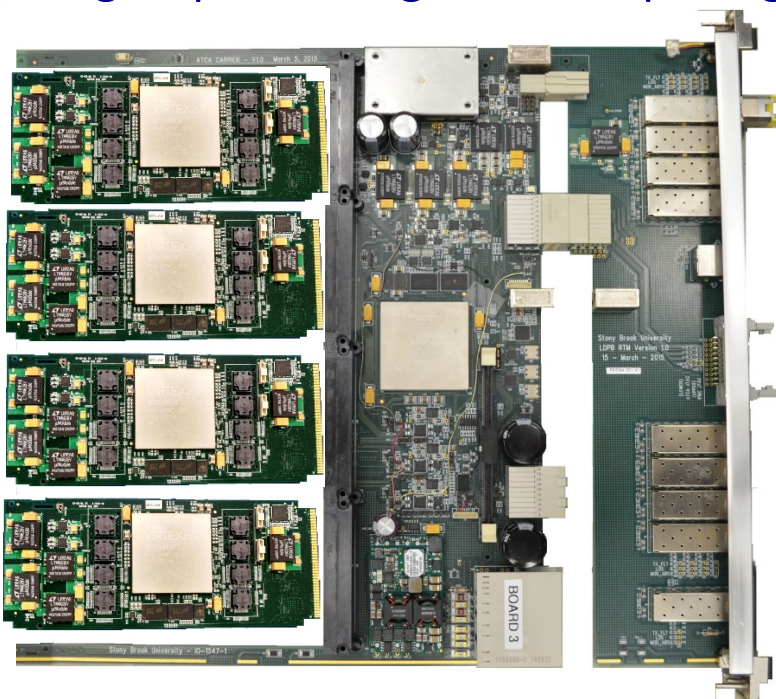




HL-LHC LAr BE Electronics

- LPPR of HL-LHC is natural “evolution” of ATCA-based Phase I LDPS, developed by US groups working with European groups (primarily LAPP Annecy)

Prototype
LDPS



- As in Phase I, Stony Brook/UAr propose to develop LPPR motherboard (MB) (WBS 6.4.x.3), both hardware and firmware (140 MBs needed in total)
 - Stony Brook – emphasis on hardware
 - U Arizona – emphasis on associated firmware



System Integration

- WBS 6.4.x.4 covers “System Integration” task at BNL, which is part of DOE scope
- Work involved includes:
 - Frontend Crate System Test, performed to validate the FE system integration and overall performance before PRRs of the various FE crate boards (including FEB2)
 - Validation and final analog tests of 50% of the FEB2 boards
 - Integration and combined system test of FE and BE electronics
- The equivalent tests were performed at BNL during the original ATLAS construction





4. Cost Book & Basis of Estimate

- All cost and schedule information can be found on the review website http://www.usatlas.bnl.gov/HL-LHC/reviews/CDR_Mar_2016/cost_books.php
 - Summary and individual subproject schedules
- Cost book contains cost profiles for WBS level 2 subsystem by
 - Expense type (Labor/M&S/Travel)
 - Institution totals
 - Activity phase (e.g. Design/Prototype/Production) by institution
 - Deliverables (and broken down by institution)
 - Labor type (Engineer/Instrumentation Physicists/Technician/Student)
- BoE contains
 - The WBS dictionary definition for WBS level 4 systems
 - Identification of the Cost Estimate type (GAO categories)
 - Explanation of the work
 - Cost Estimate details
 - Assumptions
 - Schedule
 - Risk Identification and analysis
 - Backup material (quotes, est., etc)

Mike Tuts

ATLAS HL-LHC Conceptual Design Review, March 8-10, 2016, NSF

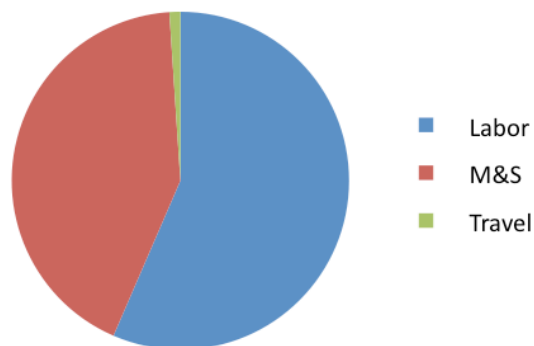
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From Mike Tuts' talk



NSF Budget and Effort

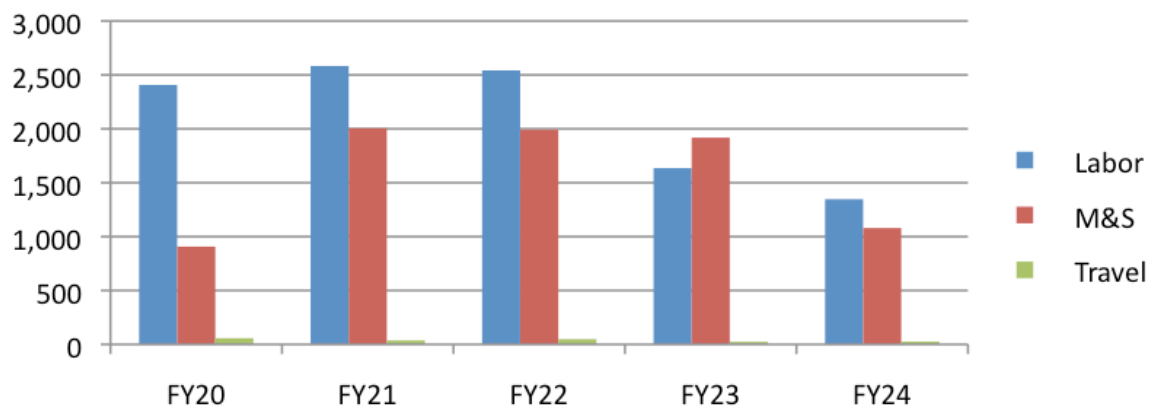
WBS 6.4 LAr NSF Resource Breakdown



6.4 Liquid Argon NSF Total Cost (AYk\$)

	FY20	FY21	FY22	FY23	FY24	Grand Total
NSF						
Labor	2,407	2,582	2,541	1,635	1,347	10,512
M&S	907	2,005	1,991	1,918	1,079	7,900
Travel	57	37	49	25	26	195
NSF Total	3,371	4,624	4,581	3,578	2,453	18,607

WBS 6.4 LAr L2 NSF Fiscal Year Costs AYk\$

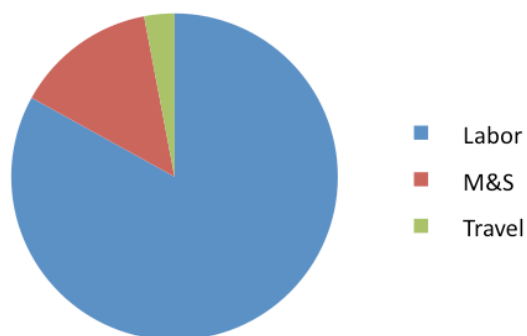




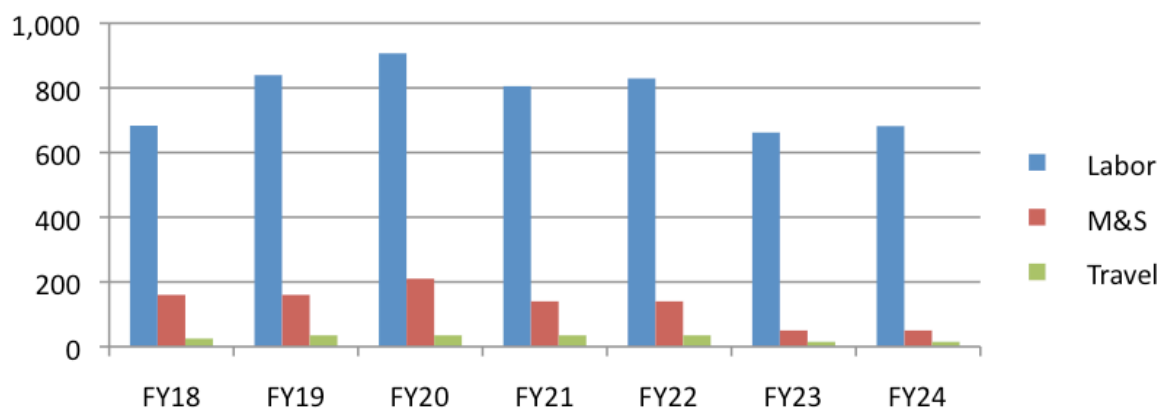
DOE Budget and Effort

6.4 Liquid Argon DOE Total Cost (AYk\$)								
	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Grand Total
DOE								
Labor	683	839	907	805	829	662	682	5,408
M&S	160	160	210	140	140	50	50	910
Travel	25	35	35	35	35	15	15	195
DOE Total	868	1,034	1,152	980	1,004	727	747	6,513

**WBS 6.4 LAr L2 DOE
Resource Breakdown**

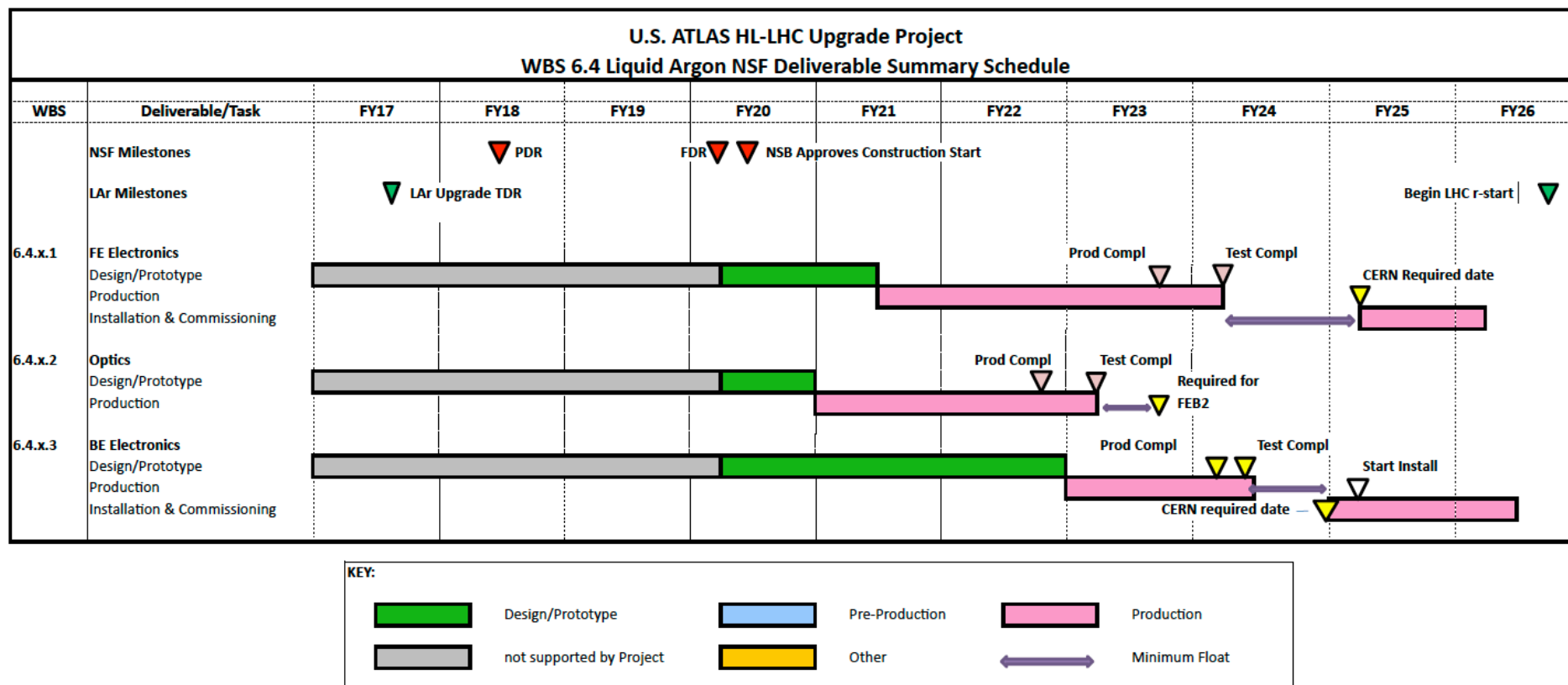


**WBS 6.4 LAr L2
DOE Fiscal Year Cost AYk\$**





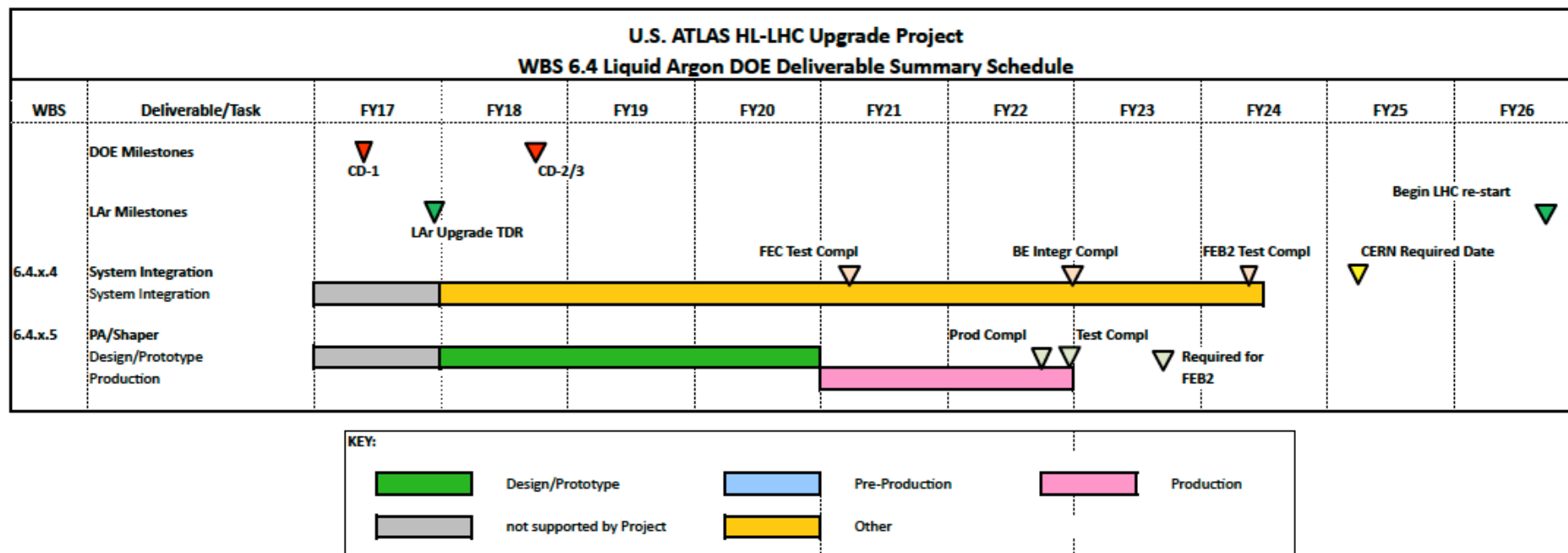
NSF Schedule & Milestones



- US schedule developed to be consistent with LAr milestones presented in Scoping Document
- Planning includes 6-12 months of schedule float



DOE Schedule & Milestones



- US schedule developed to be consistent with LAr milestones presented in Scoping Document



External Dependencies

6.4	Liquid Argon			
6.4.x.1	FE Electronics	Frontend Board (FEB2)	PA/shaper ASIC (BNL/UPenn - DOE scope)	Maintain tight coordination and oversight via System Engineering. Well-advanced SiGe version is a backup in case of problems with development of baseline in 65 nm CMOS. Complementary efforts underway in France.
6.4.x.2	Optics		Project self-contained in NSF scope	
6.4.x.3	BE Electronics	LPPR Motherboard (MB)	Mezzanine card (France)	Clearly define, with help from System Engineering, interfaces between MB and mezzanines. Develop mezzanine-style test cards that will allow MB to be fully tested and qualified even without final mezzanines being available.

- Have worked to minimize potential impact of external delays
 - FEB2 and LPPR MB production testing and validation/acceptance procedures will be clearly defined to minimize reliance on external deliverables
 - System Engineering plays important role, ensuring interfaces are properly defined, etc.
- PA/shaper ASIC is essential component of production FEB2 boards
 - Baseline and (well-advanced) backup developments are part of DOE scope, and will be tightly coordinated within US ATLAS
 - There is also complementary development effort in France



Risks

HL-LHC Upgrade Project Risk Registry for L2 Systems January 4, 2016			Risk Evaluation (L/M/H)						Identified Risks (See BoEs)
WBS	Title	Risk Owner	Cost	Schedule	Scope	Contingency %	Contingency AYk\$	Average Risk Score	
6.4	Liquid Argon	Parsons, John				35%	8,792	4.5	
6.4.x.1	FE Electronics	Parsons, John	M	M	L	35%	3,645	5.0	*Problems that can only be found at bench test and system integration test may impact project schedule. *Delays in ASIC schedule can lead to assembly schedule delays. *Achieving the required performance might require additional engineering effort. *Given preliminary nature of FEB2 design, final cost could be higher.
6.4.x.2	Optics	Parsons, John	M	L	L	35%	1,188	3.5	Delay in 1pGBT project may impact ASIC design. *Additional engineering could be effort required for ASIC. * Finding vendor qualified to assemble OTx
6.4.x.3	BE Electronics	Parsons, John	M	M	L	35%	1,840	5.0	*Problems that can only be found at bench test and system integration test may impact project schedule. *Complexity of board requires complex manufacture and assembly process, needs more iterations. *A vendor part may require an intervention at the level of design of the overall system and some modifications of the assemblies.
6.4.x.4	System Integration	Parsons, John	M	M	L	35%	1,098	5.0	*Problems that can only be found at integration stage may impact project schedule and require modifications to one or more components. *A vendor part may require intervention at the level of design of the overall system and some modification of the assemblies.
6.4.x.5	PA/Shaper	Parsons, John	M	L	M	35%	1,021	4.5	*Problems that can only be found at bench test and system integration test may impact project schedule, requiring additional engineering work.. *Late delivery of ASICs. *Analog circuits can require multiple submissions due to unforeseen performance or manufacturing issues.

DOE
Scope

- Leading risks, and mitigation strategies, identified in BOEs
 - For example, cost and schedule risks in custom ASIC development, common fabrication run, ...



Contingency

Budget Contingency

- Following rules adopted for assigning contingency at this conceptual design stage, 35% budget contingency assigned top-down to all LAr deliverables
- A risk-based bottom-up contingency analysis is being developed

Scope Contingency

- Provide less firmware effort for BE MBs (up to ~ \$1M)
 - Decision up to FY22; would provide only minimal firmware to allow testing and validation of production MBs
- Cover M&S for < 67% of FEB2 boards/OTx modules/BE MBs (up to \$1M)
 - Decision by FY20; would need to renegotiate (at level of overall ATLAS) final cost sharing

Scope Opportunity

- Cover M&S for > 67% of FEB2 boards/OTx modules/BE MBs (up to ~ \$2.4M)
- HGTD contribution (up to ~ \$5.3M)



Summary and Next Steps

- Srini will discuss the next steps in the planning, and the generation of a task list for each deliverable, as we move toward the resource-loaded schedule that will be needed for CD1, CDR, ...
- I have uploaded to Indico the BOEs and spreadsheet as they were at the time of the CDR
 - This reflects the status of the planning ~2 months ago, so you should start by going over your BOE and the corresponding spreadsheet numbers, and contact me (and your institutional PIs) with questions
 - The very urgent task is to start dividing the work into a sequence of tasks (see more from Srini's talk)
- We will meet again next Monday to discuss the status, review any questions, etc.



Backup Slides



LAr Electronics Radiation Tolerance

Table 14. Radiation tolerance criteria of the LAr electronics for operation at HL-LHC for a total luminosity of 3000 fb^{-1} , including safety factors for background estimation, given in brackets. For COTS, an additional safety factor of 4 is included in case of production in unknown multiple lots. Furthermore, the ATLAS policy specifies annealing tests that allow reducing the enhanced low dose rate safety-factor to 1, which currently is set to 1.5 for ASICs and 5 for COTS.

	TID [kGy]	NIEL [$n_{\text{eq}}/\text{cm}^2$]	SEE [h/cm^2]
ASIC	0.75 (2.25)	2.0×10^{13} (2)	3.8×10^{12} (2)
COTS (multiple lots)	9.9 (30)	8.2×10^{13} (8)	1.5×10^{13} (8)
COTS (single-lot)	2.5 (7.5)	2.0×10^{13} (2)	3.8×10^{12} (2)
LVPS (EMB and EMEC)	0.58 (30)	9.2×10^{12} (8)	2.4×10^{12} (8)
LVPS (HEC)	0.17 (2.25)	4.7×10^{12} (2)	2.7×10^{11} (2)



LAr Electronics CORE Costs

WBS ID	Upgrade Item	All Cost Scenarios [kCHF]
3.1	LAr Readout Electronics	31,394
3.1.1	LAr Front-end Electronics	20,427
3.1.1.1	Front-end Boards (FEB-2)	9,743
3.1.1.2	Optical fibres and fibre plant	4,306
3.1.1.3	Front-end power distribution system	3,123
3.1.1.4	HEC LVPS	622
3.1.1.5	Calibration System	2,484
3.1.1.6	Shipping and Logistics	150
3.1.2	LAr Back-end Electronics	10,967
3.1.2.1	LAr Pre-processor Boards (LPPR)	10,212
3.1.2.2	Transition modules	122
3.1.2.3	ATCA shelves	66
3.1.2.4	ATCA switches	76
3.1.2.5	Server PC	22
3.1.2.6	Controller PC	8
3.1.2.7	FELIX/TTC System	460



LAr Electronics Schedule (from SD)

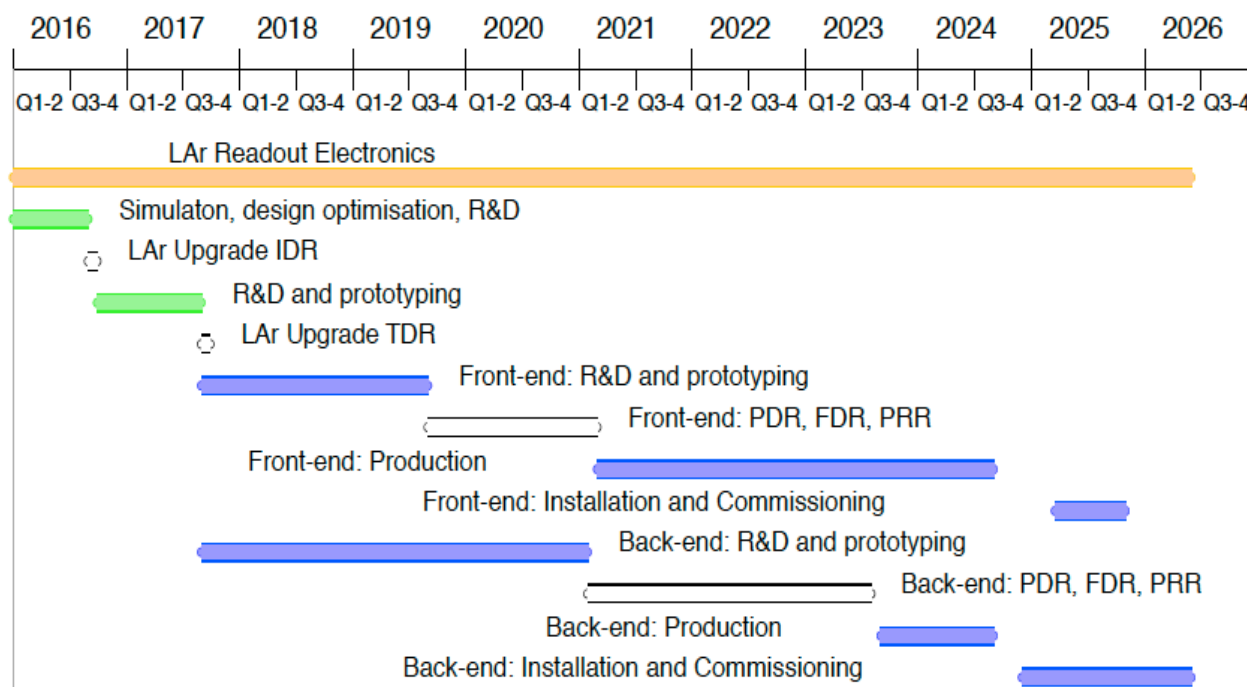


Figure 26. Overview of the time-line and milestones for the main system components of the front-end and back-end systems of the LAr readout electronics upgrade.



From CDR

NSF Cost and Effort (by Deliverable)

6.4 Liquid Argon Total NSF Cost by Deliverable (AYk\$)						
Deliverable/Item	FY20	FY21	FY22	FY23	FY24	Total
FE Electronics	1,451	2,595	2,758	2,232	1,378	10,414
6.4.1.1 FE Electronics	1,333	2,474	2,634	2,117	1,260	9,818
6.4.2.1 FE Electronics	119	121	123	115	118	596
Optics						
6.4.3.2 Optics	991	1,115	1,116	173	0	3,396
BE Electronics	929	914	708	1,172	1,075	4,798
6.4.4.3 BE Electronics	765	686	504	995	948	3,898
6.4.5.3 BE Electronics	164	228	204	177	126	900
NSF Grand Total	3,371	4,624	4,581	3,578	2,453	18,607

6.4 Liquid Argon NSF Total FTEs by Deliverable						
Deliverable/Item	FY20	FY21	FY22	FY23	FY24	Grand Total
FE Electronics	6.60	6.95	7.85	7.00	6.50	34.90
6.4.1.1 FE Electronics	5.60	5.95	6.85	6.00	5.50	29.90
6.4.2.1 FE Electronics	1.00	1.00	1.00	1.00	1.00	5.00
Optics						
6.4.3.2 Optics	5.25	7.00	6.95	1.00	-	20.20
BE Electronics	4.39	4.47	4.17	2.89	2.14	18.06
6.4.4.3 BE Electronics	3.10	3.10	2.80	1.60	1.30	11.90
6.4.5.3 BE Electronics	1.29	1.37	1.37	1.29	0.84	6.16
NSF Grand Total	16.24	18.42	18.97	10.89	8.64	73.16



DOE Cost and Effort (by Deliverable)

6.4 Liquid Argon Total DOE Cost by Deliverable (AYk\$)

Deliverable/Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
System Integration	248	448	464	475	488	727	747	3,596
6.4.6.4 System Integration	248	448	464	475	488	727	747	3,596
PA/Shaper	621	586	688	505	516	0	0	2,916
6.4.6.5 PA/Shaper	439	452	515	417	426	0	0	2,249
6.4.7.5 PA/Shaper	182	135	173	88	90	0	0	667
DOE Grand Total	868	1,034	1,152	980	1,004	727	747	6,513

6.4 Liquid Argon Total DOE FTEs by Deliverable

Deliverable/Item	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Grand Total
System Integration	1.00	2.00	2.00	2.00	2.00	3.00	3.00	15.00
6.4.6.4 System Integration	1.00	2.00	2.00	2.00	2.00	3.00	3.00	15.00
PA/Shaper	2.73	2.43	2.80	2.00	2.00	-	-	11.96
6.4.6.5 PA/Shaper	1.50	1.50	1.50	1.50	1.50	-	-	7.50
6.4.7.5 PA/Shaper	1.23	0.93	1.30	0.50	0.50	-	-	4.46
DOE Grand Total	3.73	4.43	4.80	4.00	4.00	3.00	3.00	26.96



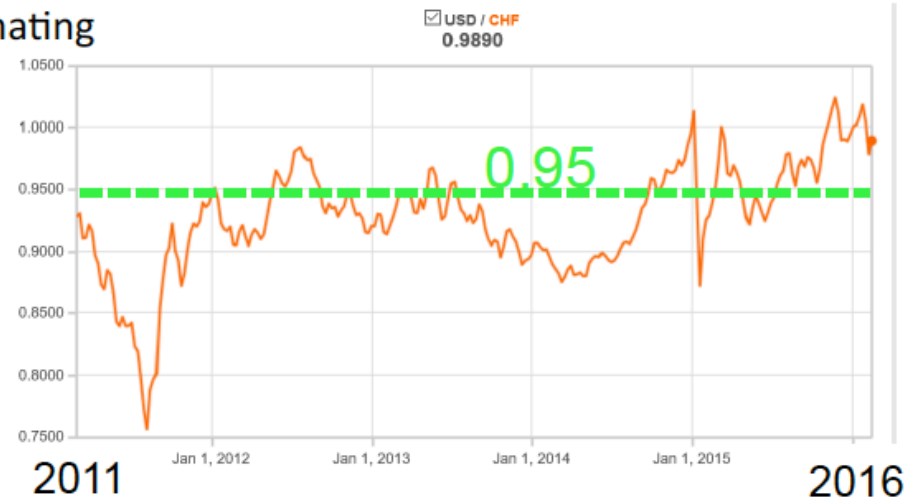
Table 26: Questions for Checking the Accuracy of Estimating Techniques

Technique	Question
Analogy	<ul style="list-style-type: none"> What heritage programs and scaling factors were used to create the analogy? Are the analogous data from reliable sources? Did technical experts validate the scaling factor? Can any unusual requirements invalidate the analogy? Are the parameters used to develop an analogous factor similar to the program being estimated? How were adjustments made to account for differences between existing and new systems? Were they logical, credible, and acceptable?
Data collection	<ul style="list-style-type: none"> How old are the data? Are they still relevant to the new program? Is there enough knowledge about the data source to determine if it can be used to estimate accurate costs for the new program? Has a data scatter plot been developed to determine whether any outliers, relationships, and trends exist? Were descriptive statistics generated to describe the data, including the historical average, mean, standard deviation, and coefficient of variation? If data outliers were removed, did the data fall outside three standard deviations? Were comparisons made to historical data to show they were an anomaly? Were the data properly normalized so that comparisons and projections are valid? Were the cost data adjusted for inflation so that they could be described in like terms?
Engineering build-up	<ul style="list-style-type: none"> Was each WBS cost element defined in enough detail to use this method correctly? Are data adequate to accurately estimate the cost of each WBS element? Did experienced experts help determine a reasonable cost estimate? Was the estimate based on specific quantities that would be ordered at one time, allowing for quantity discounts? Did the estimate account for contractor material handling overhead? Is there a definitive understanding of each WBS cost element's composition? Were labor rates based on auditable sources? Did they include all applicable overhead, general and administrative costs, and fees? Were they consistent with industry standards? Is a detailed and accurate materials and parts list available?
Expert opinion	<ul style="list-style-type: none"> Do quantitative historical data back up the expert opinion? How did the estimate account for the possibility that bias influenced the results?



4. Developing a Baseline Budget

- The goal is to have a cost estimate that is comprehensive, well documented, accurate and credible
- The cost estimate has been made bottoms up by the WBS Level 2 managers and their cost estimators at a lower level of the WBS – presented in cost breakout
- The subsystems are at different levels of maturity which is captured in the BoE's
- The cost estimation methods, identified in the BoE's, are consistent with GAO Table 26 indicated in the charge:
 - Analogy, Data Collection, Engineering build up, Expert opinion, Extrapolate from actuals, Parametric, Software estimating
- Assumptions: escalation 3%/year; exchange rate 1 USD = 0.95 CHF; using institutional labor rates



From Mike Tuts' talk

Mike Tuts

ATLAS HL-LHC Conceptual Design Review, March 8-10, 2016, NSF

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4. Basis Of Estimates (BoE)

- BoE's have been prepared for each deliverable providing details about the scope and cost justification.
 - L2 managers together and their cost estimators have prepared a bottoms up estimate
 - Evaluated and built on estimates made at the international level
 - Used initial vendor quotes, scaling from prototypes, or prior experience to estimate the costs.
 - A list of sub-deliverables (items) and associated tasks were defined for each deliverable.
 - This allowed us to estimate the amount of Labor (FTE) needed for each task. Many of these estimates are based on prior experience (incl. Phase I upgrades), working with prototypes, or discussions with engineering experts.
 - Institutional Labor rates were used in determining the associated costs that includes the standard inflation for out-years.
 - Travel costs were also included.
 - The L2 managers and cost estimators are prepared to discuss the details of these cost estimates at their respective breakout sessions.

From Mike Tuts' talk



4. Developing the Schedule

- The current schedule was developed by the WBS Level 2 managers and vetted by Project Management and the Management Team
- The principal activity types of design, prototyping and production were assessed for each deliverable and entered into Excel
 - External dependencies, where appropriate, were included in developing the schedule
 - We plan on migrating Primavera P6 by the end of the year to develop the final resource loaded schedule, but the current method we find more flexible for developing rather than tracking the schedule

From Mike Tuts' talk



Communication with International ATLAS

ATLAS Operations

U.S. ATLAS

ATLAS HL-LHC

